Activity Guide

Invention Factories

TSONGAS INDUSTRIAL HISTORY CENTER

University of Massachusetts Lowell
Graduate School of Education

Lowell National Historical Park

Connections to National Standards and State Curriculum Frameworks

Invention Factories is an interdisciplinary program designed to help students achieve state and national standards in History/Social Science, Science and Technology, and Mathematics. The working of standards varies from state to state, but there is substantial agreement on the knowledge and skill students should acquire. The standards listed below, taken from either the national standards or Massachusetts standards, illustrate the primary curriculum links made in *Invention Factories*.

History/Social Science

Students learn the story of inventions and discoveries that make their lives different from the lives of people of long ago and of even the recent past. (Massachusetts)

Students understand the effects of inventions and discoveries that have altered for better or for worse over time, working and safety conditions in manufacturing. (Massachusetts)

Science and Technology

Students develop an understanding about and abilities to do scientific inquiry; for example, observation, inference, and experimentation. (National Standards)

Students demonstrate methods of representing solutions to a design problem (e.g., sketches, orthographic projection). (Massachusetts)

Students identify appropriate materials and tools needed to construct a prototype of a given three dimensional design. (Massachusetts)

Mathematics

Students engage in problem solving, communicating, reasoning and connecting to use patterns and functions to represent and solve problems. (Massachusetts)

Invention Factories

Program Description

The Invention Factories program consists of a 60-minute interpretive tour, a 90-minute hands-on workshop and a 20-minute slide show providing students with the opportunity to explore inventions and their significance to the modern world. On the tour, students discover the unique resources of Lowell National Historical Park firsthand. The hands-on workshop complements the tour by bringing the significance of these historic resources to life as students design and build their own inventions.

Students tour the Suffolk Mill where they discover cutting edge technology of the late 19th century: turbines, power looms, and a flyball governor. Just before or just after the tour, students view *Lowell: The Industrial Revelation*, a 20-minute, multi-media show on the history of Lowell and the industrial revolution. In the workshop, students become inventors who must use their ingenuity to meet a challenge.

Theme

The Industrial Revolution was a defining era in American history. All that we consider "modern" was significantly shaped by this period, whether it be in technology, politics, art, culture, or the nature of work itself.

Brain power was combined with water power to spark the Industrial Revolution. The new American republic offered unprecedented opportunities to men and women with creative ideas for improving daily life. The deliberate attempt to invent new and better products was one of the greatest innovations of the 19th century.

Program Objectives

After visiting the Park and the Tsongas Center and completing the activities in this guide, students will be able to:

- describe the relationship between the Industrial Revolution and technological innovations.

- discover that the process of invention requires not only creativity but also planning, trial and error, and refinement.

- describe the process by which inventions are patented and explain why patents are important.

- describe how inventions have affected people, both historically and today.

Introduction

Why do human beings invent things? Why do some inventions catch on, while others don't? Who invents things? Can anyone be an inventor? Invention, design, and engineering have played important roles in Lowell's history since the founding of the city's first large-scale textile factories in the 1820s. Lowell exists today, in part, because of the invention of the power loom and design of the factory system.

Borrowing Ideas

In 1813, Francis Cabot Lowell and Paul Moody designed and built an American version of the English power loom. Lowell had drawn design plans after observing British textile operations in 1811. Together, Lowell and Moody drew and revised plans, built and tested prototypes, and spent months fine-tuning their product. The looms were successfully tested in a factory in Waltham, Massachusetts, in 1813. In 1823, the clatter of looms could be heard in the first of many mills built along the banks of the Merrimack River. The "Lowell Experiment" was underway.

Channeling Water

Over the next 25 years, Lowell engineers developed an elaborate system of power canals to channel water from the Merrimack to turn water wheels in the mills. A private company, the Proprietors of Locks and Canals, financed the construction. The guiding force behind this enormous undertaking was James B. Francis, the company's chief engineer from 1837-1885. His greatest engineering triumph was the last and largest canal, the Northern (1846-1847), which increased the power of the system by more than 50%. The canal system effectively routed all of the water from the Merrimack River through the mills, making this the largest water power system in the world.

Harnessing Energy

Francis and other engineers set their minds to improving the water wheels that converted falling water into mechanical energy. In 1847, using the Lowell system as a laboratory, Francis adapted and perfected a turbine of French design. This turbine captured more than 85% of the potential energy of falling water, far more than the earlier breastwheels. Soon, hundreds of these turbines powered mills along New England's rivers and waterways.

Francis engaged in hydraulic experiments throughout his years in Lowell. In 1855, his research and designs were published in a classic volume that established American hydraulic engineering at a world-class level. Engineers from throughout the world visited Lowell to see this amazing system. The names "Lowell" and "Francis" became synonymous with technological achievement.

Manufacturing Machinery

In the early years, the mill basement served as a machine shop where all the machinery needed to card, spin, and weave was designed and fabricated. As the number of factories increased, so did the demand for new and innovative machinery. A series of machine shops, known to historians as the Saco-Lowell shops, became the suppliers.

Founded separately in Waltham and Lowell, Massachusetts, and Saco, Maine, these pioneering foundries were centers of inovation in the mechanical arts throughout the 19th century. The finest engineers and mechanics in America crafted turbines to capture the energy of falling water; steam engines to supplement the waterpower; flywheels, lineshafts, and leather belts to transmit power; cards, spinning frames, and power looms to transform raw cotton into woven cloth; and railroad locomotives to pull freight trains transporting raw material to the mills and finished goods to market.

Designing New Patterns

Lowell was home to other kinds of design work and invention as well. Patterns for weaving cotton cloth became more intricate as the industry responded to, and, in turn, influenced changing American fashions. Working out patterns on power looms demanded artistic ability, graphic design skills, mathematical computation, knowledge of plant fibers, understanding of chemical dyes, and mechanical know-how. The Lowell Textile School was established in the 1890s to teach these design processes to new generations of textile engineers.

Continuing the Tradition

The tradition of design, production, and marketing of manufactured goods continues in Lowell. Companies such as Freudenberg Nonwovens and Joan Fabrics employ designers and engineers who develop new machines and products to meet market demands. These people use many of the same skills and practices used by Moody, Lowell, and Francis: borrowing ideas, drawing designs, constructing models, and testing prototypes. At the University of Massachusetts Lowell's Toxics Use Reduction Institute, scientists help reduce the production and use of toxic substances by industry. The first facility of its kind in the nation, the Institute performs research to develop new, nontoxic processes and materials to replace those currently used in manufacturing. At the University's James B. Francis College of Engineering, and in engineering companies located in the city’s renovated mill buildings, electrical, mechanical, and civil engineers continue to design and test tomorrow’s inventions.

1. DRAWING AS AN EXTENSION OF SEEING

When students visit the workshop during their trip to Lowell, they will be given a problem to solve. The challenge is to design and construct a model capable of doing a specific task. This activity helps students prepare for their on-site experience.

Drawing an Object

Have each student select a favorite item to draw. If students are familiar with graph paper, have them use it to make scaled drawings of the objects. Encourage students to make their sketch as accurate as possible. To do this, they may want to use colored pens and pencils, rulers, or a circumference. Talk about the differences between preliminary and final drawings.

Building a Model

Once the drawings are finished, have students use a familiar building kit (Legos, Tinkertoys, building blocks, Lincoln Logs) to make a three-dimensional model of the item they've selected. The model, like the drawing, should resemble the original object as much as possible (i.e., ideally, a model car has wheels that turn).

Things to Think About and Ask:

- How do flat drawings show what we see?
- What is "artistic license"?
- When is accuracy not important? When is it important?
- What are some of the different ways color can be used in artistic and technical drawings?
- How are technical drawings different from artistic drawings?

2. HOW DOES IT WORK

This activity challenges students to think critically about how everyday things really work. Once students have studied an object, system, or machine of their choice, they must use language and graphic arts to convey to a classmate the mechanics of what they've studied.

Selecting an Everyday Object to Study
Have students pick a familiar object. Their task is to study the object carefully until they understand how it works and feel they can explain its mechanics to others.

Writing a "User's Manual"
Assign each student the task of preparing a "User's Manual" which describes how the item they studied works. The manual should contain labeled drawings and explanatory text. Caution students that they are not to refer to the original instruction manual when composing their "User's Manual."

Using the Manual
Once the manuals are completed, have each student exchange his/her manual with a classmate. Encourage students to try to use the manuals. You may want them to jot down any difficulties they have when using the manuals. Finally, have students compare the "User's Manuals" they've written with the original manuals.

Things to Think About and Ask:

- Who writes instruction manuals for the things we buy?
- Would you like to do this as a job? Why or why not?
- Who decides what to call things or parts of things?
- What happens when you can't understand instructions or when instructions are lost?

3. GEARS. BELTS, AND PULLEYS

A variety of machines are observed in the mill. They all have one thing in common—they all transfer a force from one place to another. Some machines can even transfer the direction of a force so that we can make things move in a different direction. Some machines can increase the distance and speed of a force so that we can make things move farther and faster. However, no machine can increase both force and distance at the same time—one is always sacrificed for the other.

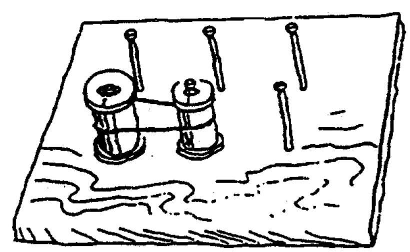
Gears and pulleys are used throughout the mill to transfer the energy from its source, which was water power in the original mills. Water would hit the vanes of the water wheel or the turbine which turned a sequence of gears that transmitted power delivered by a system of pulleys throughout the mill.

Activity

To see how power can be transmitted by a system of pulleys and wheels and to see how both speed and direction of linked wheels can be changed, make a "power board."

You will need:

- a piece of wood board about a foot square by 1/2 inch thick
- six finishing nails
- empty thread spools, four large, two small
- rubber bands



Pound the six finishing nails into the board 3 inches apart. Make a mark on the end of each spool for a point of reference to count rotations.

Have students put two large spools on the nails on the board, and join the two with a rubber band. Turn one of the spools. What happens to the other spool? Does it rotate at the same speed? The same direction?

Now try linking the larger spool to the smaller spool and turn again. Do the spools turn at the same speed?

Put a twist in the rubber band and join any two spools again. Observe the direction of rotation of each spool.

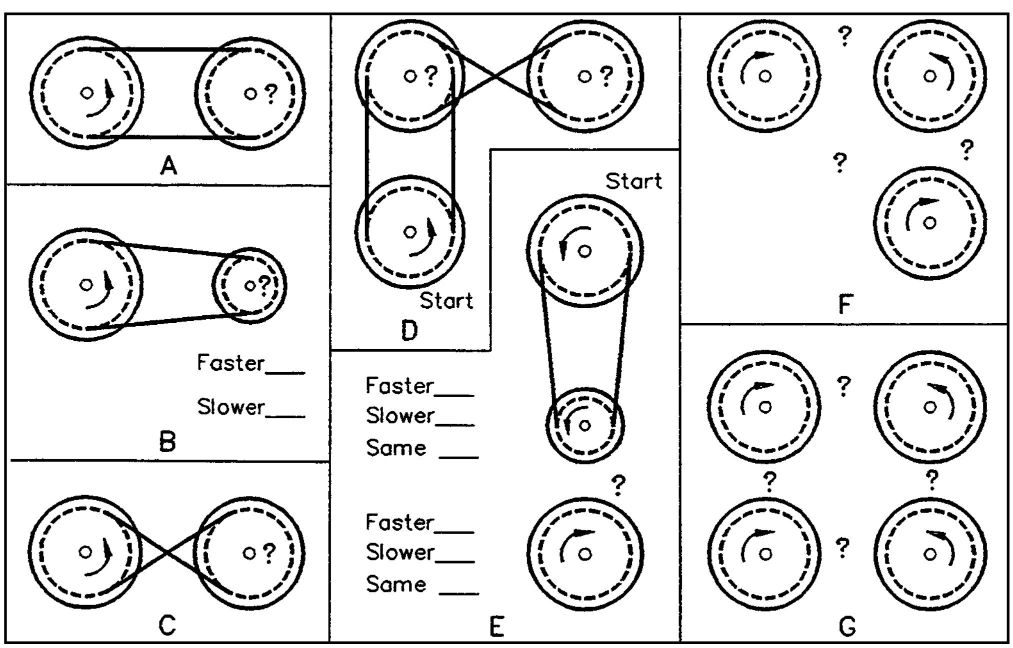
Discussion

One way of making a wheel turn another wheel is by putting a tight belt around both wheels. When one wheel is turned, it makes the belt move and turn the other wheel. The second wheel moves in the same direction as the first wheel. If we want the second wheel to move in the opposite direction from the first wheel, we cross the belt that goes around both wheels.

When the first wheel (or the driving wheel), is larger than the second wheel (or the driven wheel), we get a gain in speed, but we lose in force. When the driving wheel is smaller than the driven wheel, we get a gain in force and a loss in speed. Therefore, depending on the task we want accomplished, we have to decide whether speed or force is to be sacrificed.

Data Sheet for Wheels and Pulleys
On the power board set up these problems. Predict how you think the spools will move and record your prediction on this data sheet. Draw arrows on the spools to show the direction they will go and make a check for your speed prediction.

Diagram	*Problem*
A	If the left spool is turned, in which direction will the right spool turn?
B	In which direction will the right spool turn? Will the right spool go faster or slower?
C	In which direction will the right spool turn?
D	In which directions will the top spools turn?
E	Will the middle spool go faster, slower, or the same?
F	How should the spools be connected to make them turn as shown by the arrows. Do you need two or three bands? Draw them in.
G	How should the spools be connected to make them turn as shown?



Post-Visit Activities

1. "BACK TO THE DRAWING BOARD" GAME

During your group's visit to Lowell, students became inventors and went through the process of applying for a patent. This follow-up activity encourages students to think critically about the process of invention and the rules and regulations which inform the decision to grant or reject a patent application.

Forming Work Groups
Break the class into small groups. Inform students that they must work closely together in their groups if they are to be successful. This means listening, sharing ideas, working cooperatively, and managing time effectively.

Drawing a Winning Invention
The mission of each group is to sketch an invention which will make some aspect of school easier. Each drawing should be accompanied by a description of how the invention functions. Set a time limit on this portion of the project, and make sure each group stops drawing and/or writing when the time is up.

Sharing Ideas--Modifying Inventions
Once the drawing time is over, each group must pass its invention to another group that will modify and improve the original invention. Again, set a time limit for making modifications. Have groups continue passing the inventions around until each works on all of the drawings. At the end of the cycle, each group should have its original drawing.

Things to Think About and Ask:

- How have the inventions changed?
- Who should receive credit for the inventions in the end?
- What are some of the things that happen when groups of inventors work together?
- What roles do drawing and writing have in invention?

2. IMAGINING THE FUTURE

How will future inventions affect the classroom of 100 years from now? Have students draw their idea of what a classroom of the future would be like. Have them include at least five new inventions, with descriptions of their functions.

3. EVERYDAY INVENTIONS

Many of the things we take for granted in our environment have been around in some form or another for years and years; other things are relatively new. This activity prompts students to think about the origins and limitations of common, everyday things.

Identifying and Researching an Ordinary Item
Have students identify something they use every day at home or at school. Their task is to find out who invented it and/or when it was invented.

Presenting Their Findings
Once students have researched their item, have them present their findings in one of the following ways:

- write a one-page paper
- develop and present a documentary skit for the class
- create a visual display

Things to Think About and Ask:

- Is there a difference between when the item was first invented and when people started using it on a regular basis? Why?
- What companies make and sell this invention? Were they the original inventors and/or manufacturers?
- What was the public's response to the initial invention?
- Can you improve on this invention? How?
- How would you go about selling your improved invention?

4. TECHNOLOGY TODAY: WHAT DOES IT MEAN TO YOU?

During your group's visit to Lowell, students learned some of the ways in which technological changes led to both the success and downfall of Lowell as a textile production center. This activity encourages students to consider the different ways in which technology affects their lives, and challenges them to develop a personal definition of technology.

Understanding and Explaining the Meaning of Another's Words
Divide the class into six groups. Assign each group one quote to read from Perspectives on Technology on page 13. Once they've read the quote, they should rewrite it in language that the whole class can understand, and present an explanation to the class.

Considering Perspectives
Have the groups that studied the first and fourth quotes work together as group A, the groups that looked at the second and sixth quotes form group B, and the groups that studied the third and fifth quotes form group C. Their mission is to figure out what technology means to them. Pose the questions below or develop your own questions to get students thinking.

Questions for Group A
• What message do you think Ngoma and Jaribu Hill (Serious Bizness) are trying to get across in the verse from "High Tech"? If they could have spoken with Mary Paul, what advice do you think they might have given? Would Mary Paul have taken their advice? Why or why not?

Questions for Group B
• Nathan Appleton used the words "beautiful" and "wonderful" to describe his experience watching America's first power loom, a machine that was the most advanced of its time. What adjectives come to mind when you think about high technology today? Why?

• Read Malpas's statement. How do you think his view of technology is different from or similar to Nathan Appleton's? What kinds of technological changes do you think he would like to see? What changes would you like to see happen? Why?

Questions for Group C
• Read the quote by Colt. Imagine you are Brooke Hindle or Steven Lubar. You have been given the chance to speak with Colt. What will you say to him? What three things (places) will you show him to confirm or disprove his statement? How do you think he'll respond?

Writing a Personal Definition of Technology
Have each group present and discuss its findings with the class. Once each group

has made its presentation, have students write a one-page essay on what technology means to them, or have them make a collage using pictures to represent their ideas and feelings.

Perspectives on Technology
Read these quotations to find out some of the different ways people view technology.

"I expect to be paid about two dollars a week, but it will be very dearly earned. I cannot tell how it is but never since I have worked in the mill have I been so very tired . . . It is very hard indeed and sometimes I think I shall not be able to endure it . . . I never worked so hard in all my life . . . I presume you have heard before this that wages are to be reduced on the 20th of this month."

Mary Paul, Mill worker writing home, 1848

"There is nothing that cannot be produced by machinery."

Samuel Colt, Inventor, 1851

"[Francis Cabot Lowell] invited me to go with him and see the loom operate. I well recollect the state of admiration and satisfaction with which we sat by the hour, watching the beautiful movement of this new and wonderful machine."

Nathan Appleton,
Wealthy mill owner, 1858

"Gotta make sure it's safe, make sure it's done right; don't let speed and efficiency add misery to your life. Check it out, find out, know what this technology is all about. You got a right to know; find out, know what this technology is all about."

Serious Bizness (Ngoma and Jaribu
Hill) from the song "High Tech," 1981

"Every technological advance has come at a price--but the full price is seldom known until long after the achievement."

Brooke Hindle, Steven Lubar,
Engines of Change, 1986

"Is it not more logical to save a barrel of oil by insulating our homes than to waste . . . [it] by letting heat leak through the walls? Is it not senseless to light . . . buildings at night if no one is there? Is not an automobile that travels 24 miles on a gallon of gasoline better than one that travels half that distance on the same amount of fuel? Energy efficiency must be transformed into a significant global force."

Robert Malpas, Chair, private power
company, 1990

The Process of Invention - Some Viewpoints

Read the following quotations about invention and decide which best matches your feelings about how the inventive/creative process occurs.

"Invention is one percent inspiration and ninety-nine percent perspiration."
Thomas Edison, Inventor

"Imagination is more important than knowledge."
Albert Einstein, Physicist

"Don't quit five minutes before the miracle happens."
Anonymous

"The young do not know enough to be prudent: and, therefore, they attempt the impossible—and achieve it, generation after generation."
"All things are possible until they are proved impossible."
Pearl S. Buck,1938 Nobel Prize in Literature

"Great inventors and discoverers seem to have made their discoveries and inventions as it were by the way, in the course of their everyday life."
Elizabeth Rundle Charles, English Writer

"The only people who never fail are those who never try."
Ilka Chase, TV/Radio Personality

"Do not let what you cannot do interfere with what you can do."
John Wooden, Basketball Coach

"Somewhere, something incredible is waiting to be known."
Carl Sagan, Astronomer

"Discovery consists of seeing what everybody has seen and thinking what nobody has thought."
Albert Szent-Gyorgyi,
Hungarian-American Biochemist

"Remember to always think for yourself and listen to your ideas, even if they sound crazy at first."
Sarita M. James,Inventor

"Once you move beyond your fear of taking a risk, you'll realize that inventing can be really rewarding."
Kellyann Coors, Inventor

"Necessity is the mother of invention."
Anonymous

TERMS

canal - A human-made waterway used for transportation or power.

chute case - A turbine part that guides water from penstock to runners.

flywheel - A heavy wheel attached to machinery to regulate speed and maintain smooth rotary moton.

gatehouse - A structure on the canal with mechanisms to open and shut gates that control the flow of water to or from another canal or channel.

head - the height or vertical distance water falls to supply a mill with power.

headrace - A channel that carries water to a mill.

Industrial Revolution - The period of time when people started to make products in factories using machines, instead of making things by hand.

integrated manufacturing system - A system of manufacture in which all aspects of production take place under one roof.

lineshaft - A long bar that transfers power from the flywheel to individual machines by means of belts and pulleys.

operative - A factory worker responsible for tending machines.

patent - The exclusive right to own, use, and dispose of an invention. Patents for inventions are granted to the owner for 17 years; then the patent expires.

penstock - A tube or tunnel used to bring water from canal to turbine.

power loom - A machine used to weave cloth; run by something other than human power (e.g. water, steam, electricity).

runner - A turbine part; blades propelled in a circular motion by the force of water.

tailrace - A channel that carries water from a mill back to a river or to another mill.

technology - The ideas and tools that enable people to do the things they want to do and make the things they want to have.

turbine - An improved instrument for harnessing water power; 80-90% efficient.

water wheel - An early device that uses the weight of falling water to generate power; 40-60% efficient.

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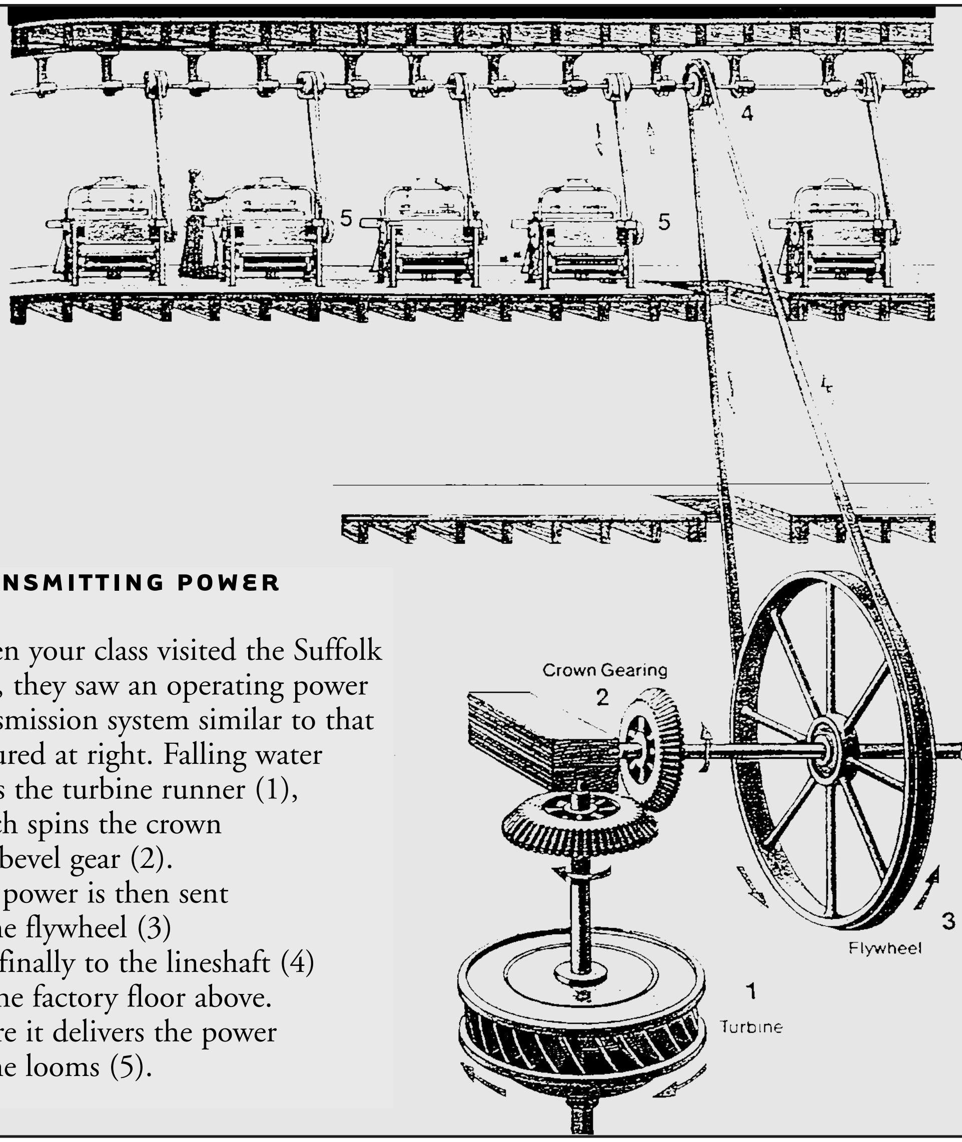
TRANSMITTING POWER

When your class visited the Suffolk Mill, they saw an operating power transmission system similar to that pictured at right. Falling water spins the turbine runner (1), which spins the crown and bevel gear (2). The power is then sent to the flywheel (3) and finally to the lineshaft (4) on the factory floor above. There it delivers the power to the looms (5).



The Tsongas Industrial History Center is a joint educational enterprise sponsored by the University of Massachusetts Lowell and Lowell National Historical Park. Established in 1987, its goal is to encourage the teaching of industrial history in elementary and secondary schools.

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